The Case for Broadband

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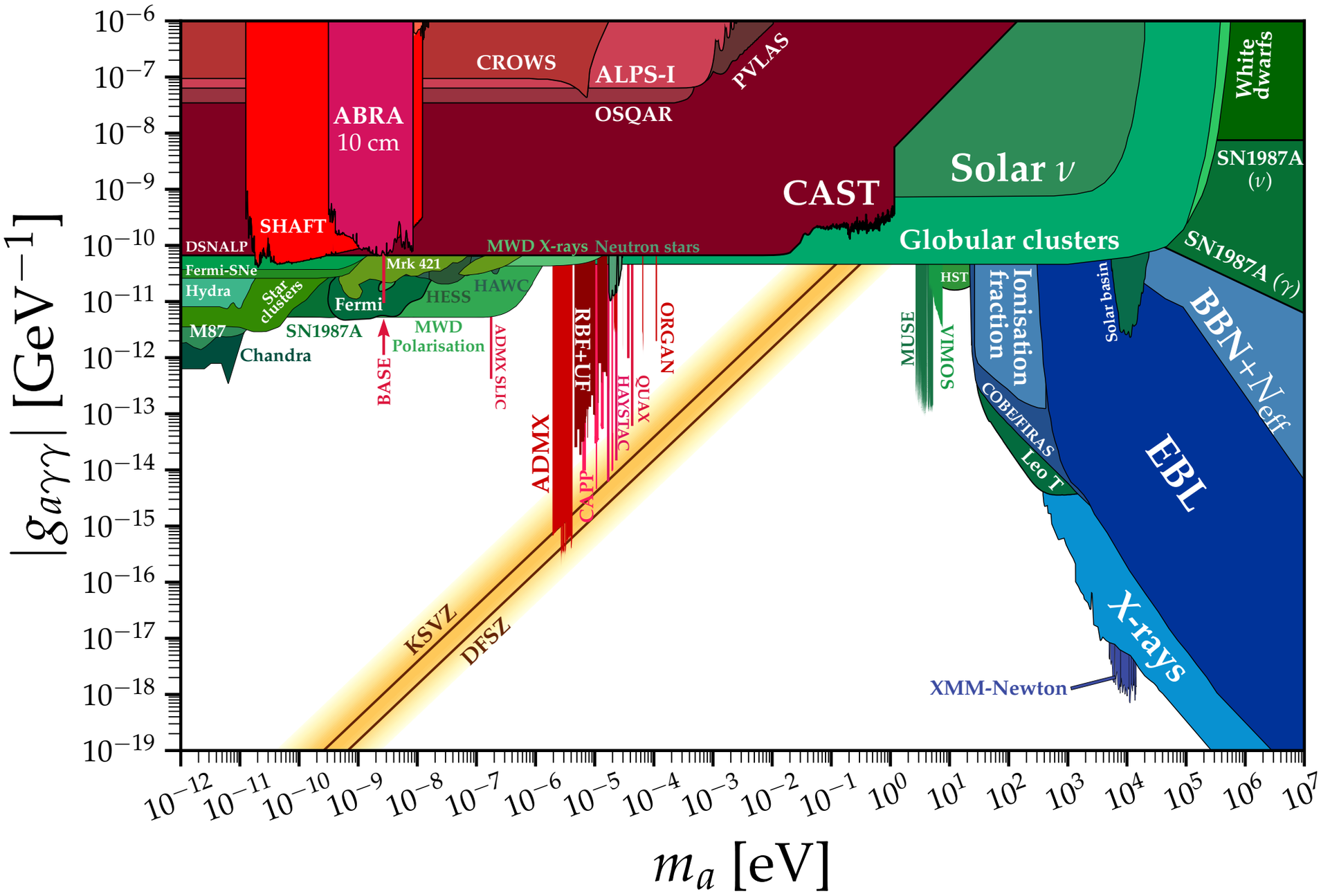
Disclaimer

This is my own personal set of viewpoints.

Please hold the rotten tomatoes until the end of the talk

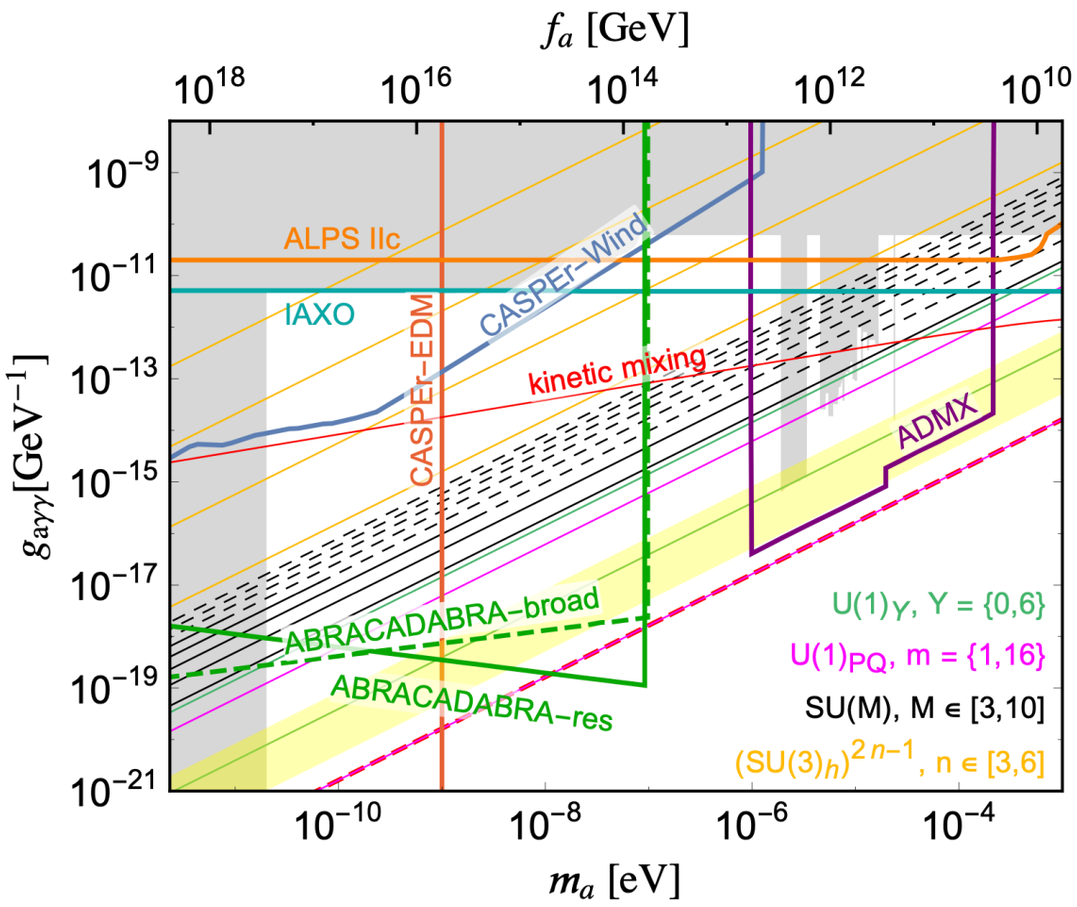
Axion parameter space

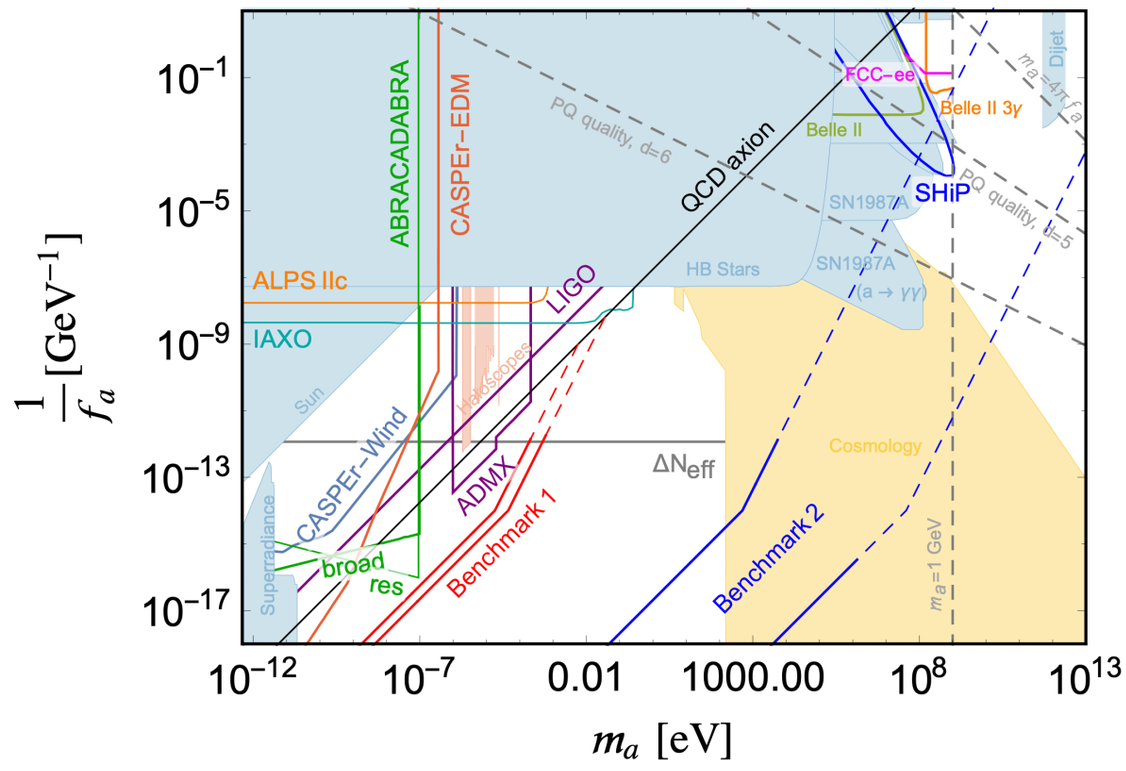


QCD is a target…but lots of white space. **Models live everywhere.**

Axion parameter space

If you allow for more than one axion…





models live above the QCD line…

…and below

We have finite time and finite resources. What is our prior?

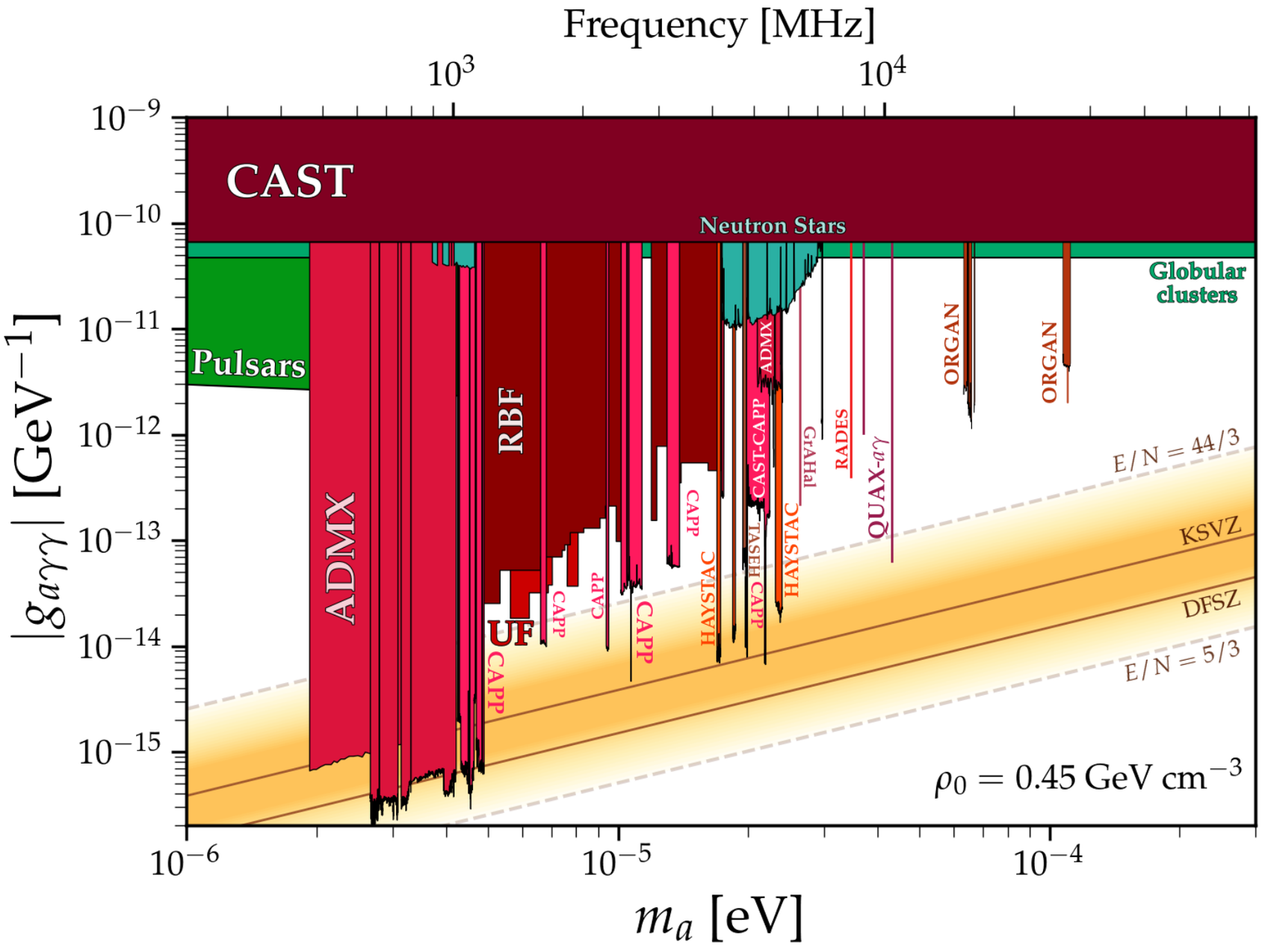
Hard truths about scanning

$$R \propto \left(\frac{g_\gamma^4}{\mathrm{SNR}'^2}\right)\left(\frac{\rho_a^2 Q_a}{\Lambda^8}\right)\left(\frac{B_0^4 V^2 C_{mnl}^2 Q_0}{N_{\mathrm{sys}}^2}\right) \propto \nu^{-14/3}$$

Equation (2.20) implies that today's leading haloscopes [91, 107] would take 20 millennia to scan *only* the 1–10 GHz frequency decade at DFSZ sensitivity, generously assuming noise at the quantum limit and 100% live time. To emphasize just how optimistic even this 20 millennia figure is, consider a more pessimistic assessment: using only noise levels achieved before this work, a more realistic live time of 10%, and $\zeta = 3$ in Eq. (2.18), a less optimistic dark matter density of $\rho_a = 0.3$ GeV/cm^3 (Footnote 15), and aiming for roughly $g_\gamma^{\mathrm{DFSZ}}/10$ to probe the entire QCD band (yellow region in Fig. 2.4) yields $\sim$ 200 trillion years for the 1–10 GHz decade!

[33] On its own, a threefold scan rate enhancement is insufficient to solve a 20,000+ year problem. The real utility of the advances discussed in this work is that they naturally invite further innovation in both quantum measurement and scan strategy. The threefold scan rate enhancement achieved herein can additionally be combined with future improvements to live times, magnets [132], and cavities [92, 109, 133]. While 20,000 is a large number of years, $\log_3(20000)$ is not so large a number of comparable scan rate enhancements needed to make the problem quite tractable.

Recent haloscope limits



The DM density

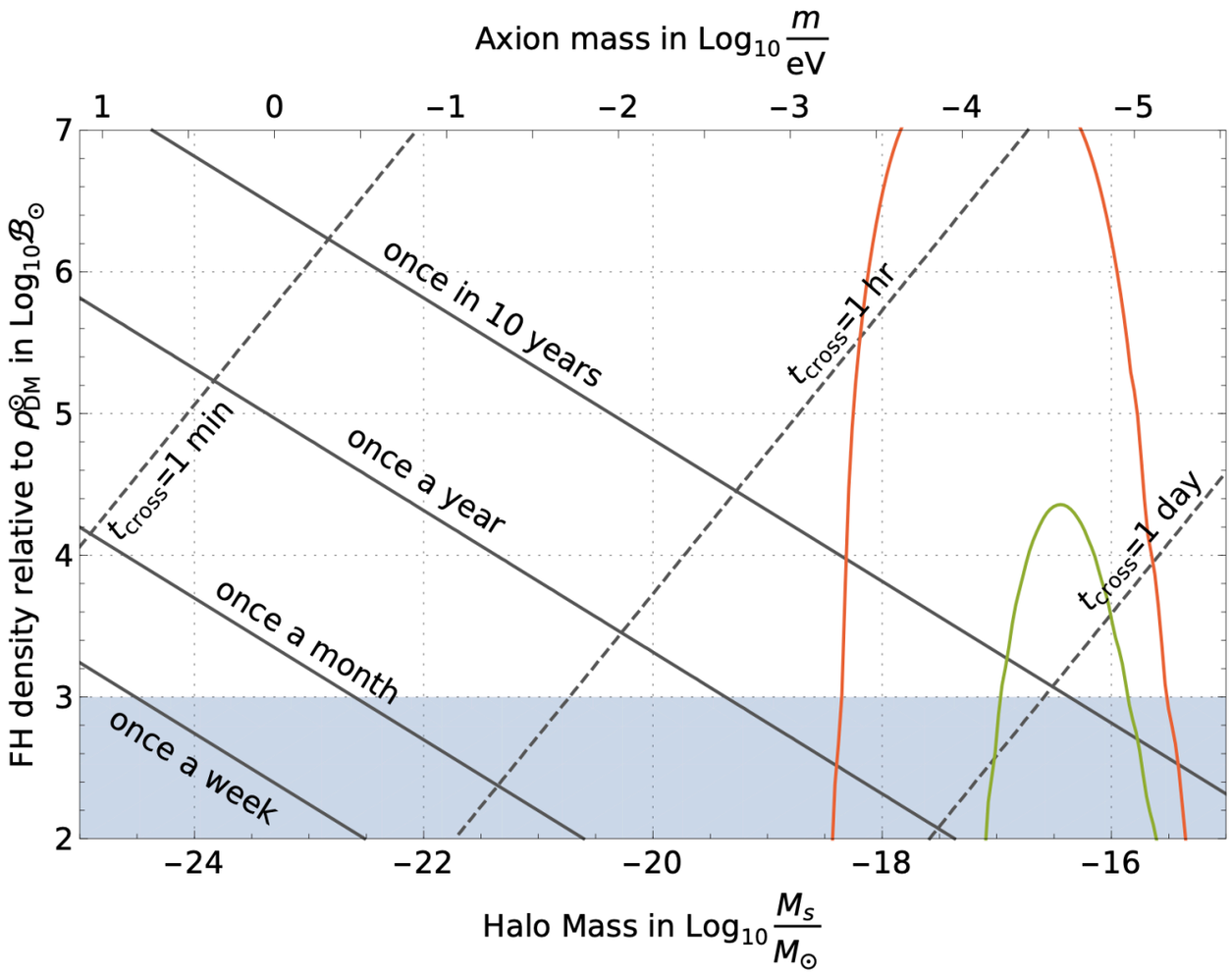
The local DM density is uncertain to 50%. Maybe even more, depending on axion substructure (which may be considerable)

$$g_{a\gamma\gamma}^{\rm lim.} \propto (\rho_{\rm DM}\sqrt{t_{\rm int.}})^{-1/2}$$

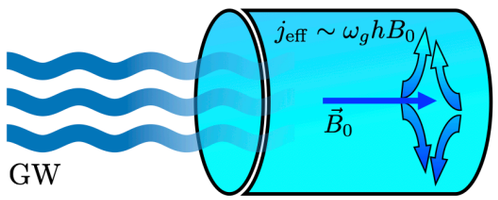
DM density smaller by factor of 2:
a 10-year experiment (2 Ph.Ds) becomes a
40-year experiment (an entire research lifetime)

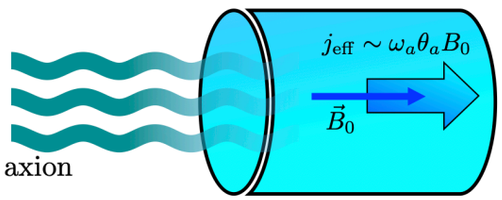
Transients

Axion clumps ("femtohalos")



High-frequency GWs from e.g. PBH mergers

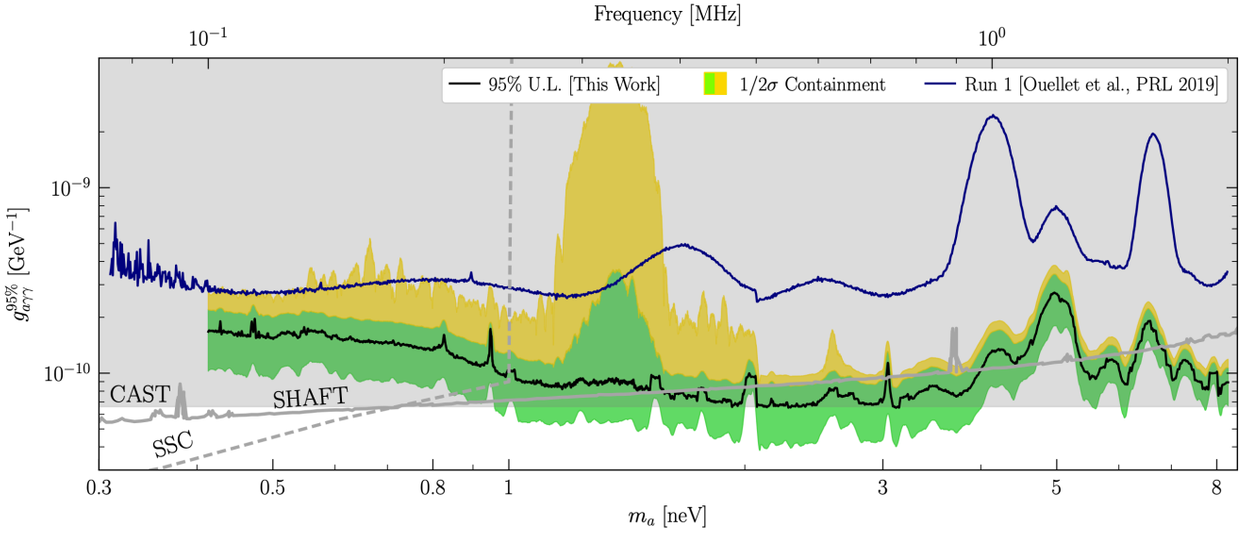




$$\tau_b \sim 10^{-3}\,\mathrm{s}\left(\frac{10^5}{Q}\right)\left(\frac{10^{-11}\,M_\odot}{M_b}\right)^{5/3}\left(\frac{1\,\mathrm{GHz}}{\omega_g}\right)^{8/3}$$

Can't go back and rescan!

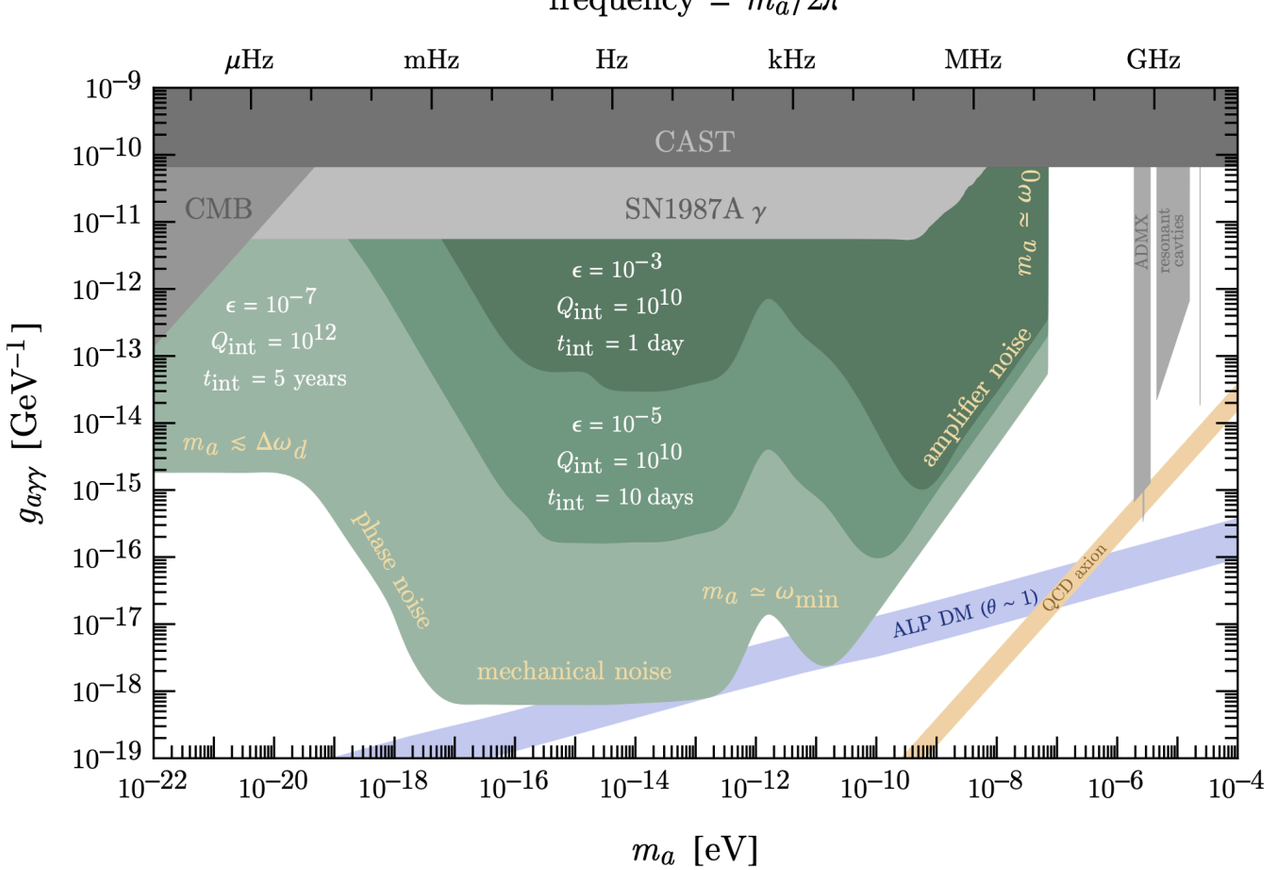
Broadband: not optimal, but easier!



ABRACADABRA
(>1 decade w/430 hrs data taking)

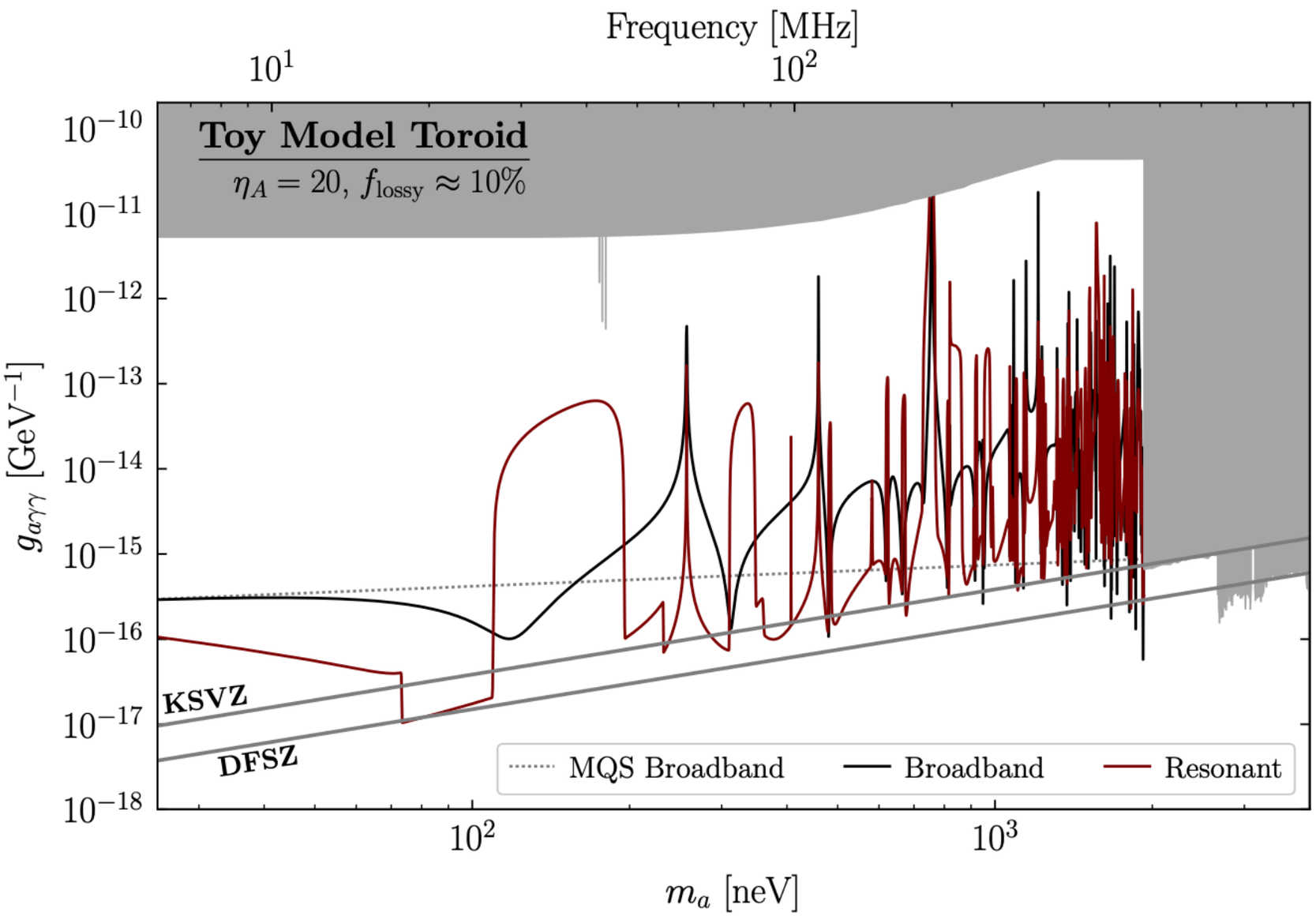
SRF heterodyne projections
(huge chunk of
parameter space in days!)

[also MADMAX, BREAD, etc.]



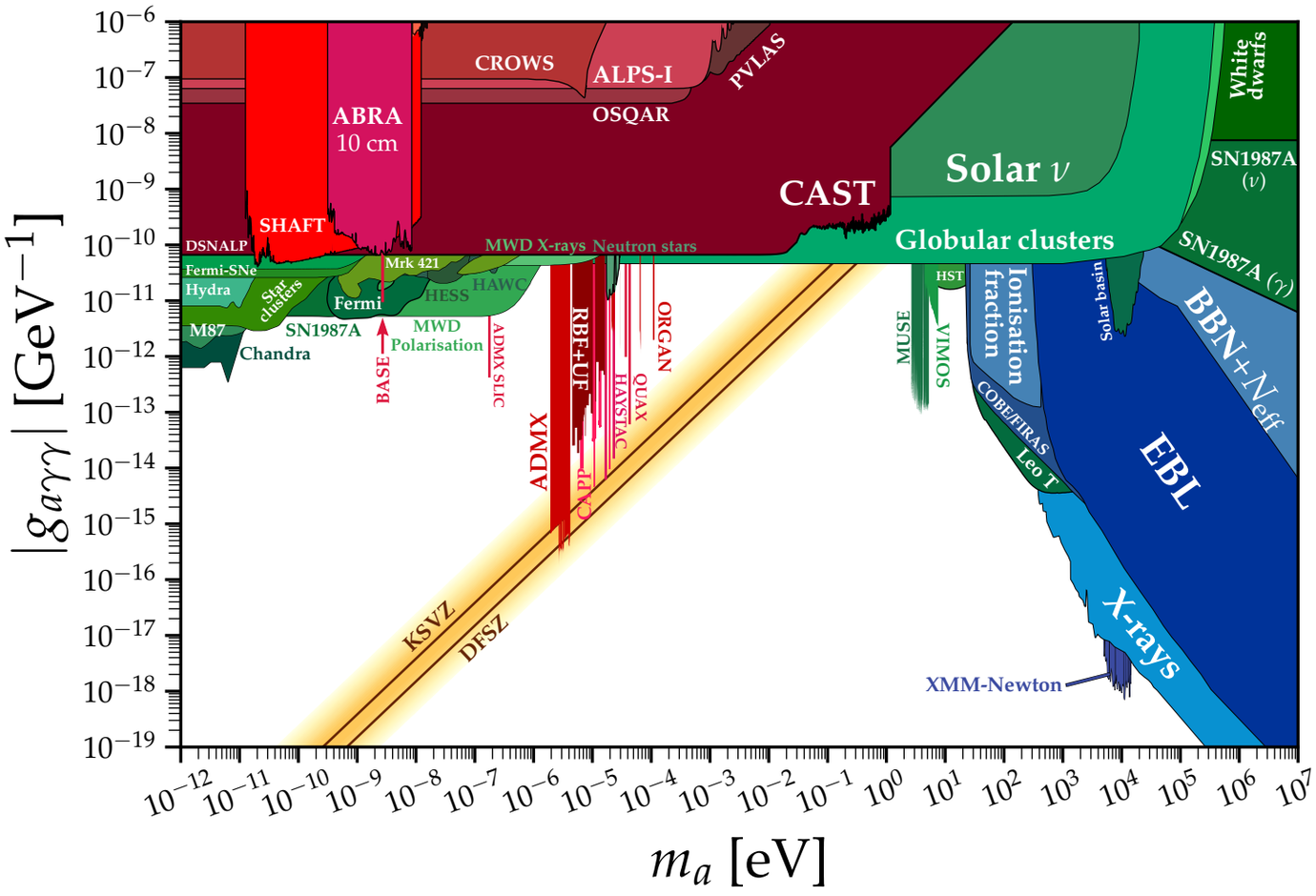
How can Dark Wave Lab help?

$$g_{a\gamma\gamma}^{\text{broad.}} \propto t_{\text{int.}}^{-1/4} B^{-1} V^{-5/6}$$



broadband is quite comparable to resonant on a log-log plot… (see J. Foster talk tomorrow)

Outlook: the case for broadband



No one asked DM to solve two problems at once. The canonical QCD band has its own nasty fine-tuning problems (axion quality, etc.)
A defensible prior is log-flat in coupling and mass.
Let's start carving into that whitespace!